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ABSTRACT

This paper describes prominent cognitive psychology techniques and considers the extent to which these techniques are being used in instructional research studies reported in publications of the Association for Educational Communications and Technology (AECT). Four techniques from cognitive psychology are described: secondary task techniques, eye-movement records, verbal reports, and representations of cognitive structures. An examination of 283 articles published in the field of instructional technology revealed that only six of the articles that examined the effects of instructional variables on learning outcomes and claimed a cognitive psychology framework used the techniques described above. The reasons for such minimal consideration of these techniques are considered, and it is suggested that many researchers may not be aware of the techniques and their potential. (34 references) (EW)

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Cognitive Psychology: Implications for Selection of Techniques and Measures in Instructional Research

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COGNITIVE PSYCHOLOGY: IMPLICATIONS FOR SELECTION OF TECHNIQUES AND MEASURES IN INSTRUCTIONAL RESEARCH

Bruning (1983), among many others, reports a clear metatheoretical shift in the field of instructional design and technology from a behavioristic framework to a cognitive framework.
Gagne and White (1978) describe the cognitive theories that have contributed to this framework:

> These theories support the basic notion that the effects of instruction may best be understood by exploring the three-term relation Instruction-Memory Structure-Learning Outcome. In other words, the suggestion is made that the effects of instruction may be explained by taking into account the processing of various forms of instruction by the learner, the first results of which are the acquisition of particular kinds of new memory structures. The latter structures, in turn, are antecedents that enable the human learner to display retention and transfer in terms of new performances (p. 187).

This cognitive perspective is further described by Wittrock (1979):

> A cognitive approach implies that learning from instruction is scientifically more productively studied as an internally, cognitively mediated process than as a direct product of the environment, people, or factors external to the learner. The approach involves understanding relations or interactions between the learners' cognitive processes and aptitudes, such as attribution, motivation, encoding, memory, cognitive styles and cognitive structures, and the characteristics of instructional treatments (p. 5).

The predominant theories that are identified with cognitive psychology as it relates to instruction are gestalt theory, information processing theory, and schema theory. These theories postulate the effects of instruction on mental structures and processes and the effects of the structures and processes on learning outcomes. Many researchers in instructional technology, particularly those who aspire to contribute to instructional theory, develop their theoretical frameworks from one or more of these categories of theory.

Although cognitive psychology may have an impact upon the theory bases from which we draw our conceptual frameworks, it appears to have had very little impact upon the dependent measures and the data-collection techniques that we use in empirical studies in our field. Posttest scores seem to the primary data source in the majority of our studies, leading some critics of research in our field to liken our studies to "horse races that only look at who (which treatment) gets to the post first."

Cognitive psychology literature has provided us with data collection techniques and dependent measures that allow us to examine the influence of

instructional manipulations on cognitive processes and structures. Identifying effective (and, perhaps, efficient and appealing) instructional treatments, which combinations of which instructional variables for which learners under which circumstances contributes to which learning outcomes, may be the ultimate goal of much of our research. However, failure to consider the mediating mechnaisms of cognitive processes and structures using these cognitive psychology techniques and measures is unfortunate because it deprives us of a) sensitive measures that may find subtle, but potentially potent, differences in instruction treatments; b) data that allow us to describe more completely what has happened to learners as a result of instruction; c) information that can help us to explain why we find differences in students' performances after different instructional treatments; and d) insight into additional questions that we may wish to investigate. In short, the omission limits our ability to refine, revise, or extend instructional theory.

The purposes of this paper are to a) describe data-gathering techniques and consequent dependent measures that are little used but have much potential in our field and b) validate empirically that these options are seldom used in instructional design and technology studies.

Potential Techniques and Measures

This section will describe the following four categories of data-gathering techniques and their consequent dependent measures:
a) secondary task techniques, b) eye-movement records, c) verbal reports, and d) representations of cognitives structures. Each technique and measure will be discussed in terms of processes or structures which they are hypothesized to indicate and advantages and disadvantages of each.

Secondary Task Techniques

Instructional researchers that use secondary task techniques ask the subject to complete a primary task, the learning task (such as responding to instructional materials), and at the same time give some attention to a less important, secondary, task. Generally, the variable of interest to the researcher is the latency, the speed of performance of the secondary task. Most often, this type of technique and measure is used within a limited capacity model of working memory. The model postulates that the longer it takes the subject to respond to the secondary task, the greater the amount of working memory is dedicated to the primary, learning, task. Special equipment is generally required to use this type of measure, as cognitive operations may occur very fast, 1 - 250 milliseconds (Gagne, 1985).

Britton, Piha, Davis, and Wehausen's study (1978) is example of the utility of this technique. Previous research had established that inserted questions in textual materials improved comprehension. Britton et al. questioned why this occurs. In their study, one-half of the subjects received inserted questions, the other half received text only. During the reading task, the subjects were given a secondary task of responding to audible clicks by releasing a button. As the researchers predicted, the students in the inserted questions group had longer response latencies than the text-only group and, as with past research,

their comprehension was greater. Britton et al. interpreted this result to indicate that comprehension was greater by those subjects that received inserted questions because the questions caused the learners to invest greater cognitive capacity (e.g., to try harder) in the learning task.

Levin, Dretzke, McCormick, Scruggs, McGiven, and Mastropieri (1983) collected latency data for a different purpose. In their studies investigating the effects of using a mnemonic picture strategy on learning the order of the U.S. presidents, one-half of the learners were taught a mnemonic strategy for remembering verbal information, the remaining half of the learners, the control group, were allowed to use any strategy they wished. During the recall test, the researchers timed the delay between the presentation of the question (e.g., "which number was Lincoln?") and the subject's response. They found that the response latency for subjects in the experimental group was significantly longer than for those in the control group. The investigators concluded that this difference was due to the "complex retrieval demands" of the mnemonic strategy, an evidence of the stubjects' using the strategy.

A major disadvantage of such approach is the difficulty in acquiring the equipment to record and analyze reponse times. In addition, there have been some criticisms of the inferences that can be made based upon such data. For example, learners seem to be able to learn to accommodate the secondary task with practice until response becomes almost automatic, regardless of the depth of processing required by the primary task (see Fisk, Derrick, & Schneider, 1982; Jacobs, Dempsey, & Salisbury, 1987) (See Britton, Meyer, Hodge, and Glynn (1980), Kahneman (1973), and Kerr (1973) for additional information on this technique.)

Eye-movement Records

Eye-movement records provide researchers information about where and for how long a subject fixes his or her gaze upon a given display. Such data gives researchers data regarding where a subjects' attention is focused a given point in time and sequentially how this attention is changed over time. Eye fixations (periods of time when eyes cease motion) may also give investigators some indication of the points at which learners pause to reflect, providing information of how learners "chunk" information. Eye movements, such as "look forwards" and "look backs," may provide information as to points at which confusions arise. (For more information on interpreting eye movement data, see Farnham-Diggery & Gregg, 1975; Just & Carpenter, 1980; Snow, 1968.) Often, the processing that may be inferred by such movements is so automatic that it is unavailable to other forms of observation and is not recollectable, and, therefore, unavailable to subjects for retrospective recall (see later section on verbal reports). Eye movements may be the only source of information about some refined aspects of processing.

Eye movements may be classified a **micro** or **macro** movements (Schumacher and Waller, 1985). Micro-eye-movements are fixations, regressions, and movements that focus on individual units of a text or pictorial display. Such movements are recorded by recording the reflection of a small amount of light, usually infrared, off the cornea of the subject's eyes. The reflection of the light is recorded by a photoelectric device that is usually interfaced with or an

integral part of a computer. Equipment is generally fairly expensive and sophisticated, requiring some knowledge of computer programming to set various parameters of the equipment. Also, the equipment often requires that the subject's head movements be restricted in some way, limiting the ecological validity of the study, and, therefore, the generalizability of the conclusions.

Some studies investigating the effects of computer or print displays may not require a record of the fine-grained movements provided by the micro-movement equipment. In such cases, investigators may wish to measure macro-eye-movements. Macro-eye-movements are grosser eye movements across larger segments of the display, such as across paragraphs and pages of text. Schumacher and Waller describe three types of procedures that are suitable for recording macro-movements. The first (Whalley & Fleming, 1975) records the movement of a light-pen which the subject moves across pages of text. This technique allows the investigator to note the time that the subject spends on each segment of text, look backs, and look forwards. The second (Pugh, 1979) videotapes two images, eye movements and text of a page, through the use of a semi-silvered plate of glass. This procedure allows the investigator, by viewing the videotape, to note lookbacks, lookforwards, note taking, and hesitations. The third procedure (Hout Wolters, 1982) involves the subject moving a special pen across a text page as (s)he reads. It does not directly record the eye movements of the user. An advantage of this equipment is that it also can measure response latency and galvanic skin responses. (For more information on eye movement recording equipment see Egan & Grimes-Farrow, 1976; Gulf and Western Research Development Group, 1978; Koff, Elman, & Wong, 1971; Young & Sheena, 1975)

Fleming (1984) used eye movement equipment to record the duration of attention to word and picture elements of a display and to record the patterns of transitions between display areas. He was investigating the effects of two variables: level of complexity of information (simple vs complex) and page layout (picture first vs text first). Learner variables included in study were gender, cognitive style (field independence/field dependence), and prior knowledge. Dependent measures were durations, transitions, and sequences of eye movements. Fleming found that

- females' durations were longer overall,
- all subjects' durations were longer for complex than for simple material,
- there was an interaction between cognitive style and complexity on the number of transitions, with field independents making fewer transitions on simple materials and more transitions for complex materials than did field dependents (e.g., they adjust processing according to complexity of materials),
- males (as compared to females) tended to make more reverse transitions when given the words first layout (they tended to look at the pictures first).

In addition to the expense and complexity of such equipment, there are three other potential disadvantages of such techniques. First, as noted earlier, some of the equipment requires that both stimulus materials' and subjects' be fixed in unnatural or fixed positions. Such a requirement may limit the generalizability of the conclusions of studies using such equipment. This disadvantage seems to be more significant for the micro-eye-movement

techniques. Second, as with secondary task techniques, researchers must be cautious in the inferences regarding processing that they make in response to such data (Just & Carpenter, 1980; McConkie, Hogaboam, Wolverton, Zola, & Lucas, 1979). Such limitations may be somewhat obviated by collection of complementary data, such as verbal reports. For example, videotapes resulting from use of one of the procedures described above might be used to stimulate retrospective verbal reports. Third, these data collection techniques result in many data points that must be reduced for analysis. However, the more sophisticated micro-movement equipment often include reduction and analysis programs that produce graphic representation and other analyses of movement data.

Verbal Reports

Verbal reports are subjects' verbal statements that are made before, during, or after performing a learning task (Gagne, 1985). Verbal reports can be concurrent, occurring as the subject completes the task, or retrospective, occurring after the subject has completed the learning task. Subjects in studies using these techniques are generally asked to verbally (generally, orally) describe what they plan to do to complete the task, what they are thinking about as they complete the task, or what they did as they completed the task. The intermediate stage, describing what is thought about while completing the task, is often called a "read-think aloud" technique (Flower and Hayes, 1981).

These verbal responses are typically transcribed into written form, **protocols**, and examined for patterns of responses, **protocol analysis** (Ericsson & Simon, 1984). These protocols can be examined for such processing features as generation of mental elaborations (additional examples, inferences, comparison, analalogies, mnemonics), paraphrases, misconceptions and their rectification, summarization/review/rehearsal, organization, self-monitoring, rereading, imaging, and questioning. Reduction of the voluminous data that results from such a techique usually involves some qualitative research techniques. Using this data, researchers can look for differences in processing patterns which may be due to manipulation of instructional variables.

Levin, Dretzke, McCormick, Scruggs, McGiven, and Mastropieri (1983) used verbal report data in their study investigating the effects of using a mnemonic picture strategy on learning the order of the U.S. presidents. After they completed the learning task, subjects were asked about the strategies that they employed during the recall task. The investigators used this technique to determine the degree to which those instructed on the mnemonic strategy actually used it and whether those who were not instructed on the strategy used a similar strategy (factors which might have confounded their results).

Wedman and Smith (1986) are using a read-think aloud procedure to investigate the processing differences between subjects who are learning the relationships of camera variables from either a hierarchically organized strategy or an elaborated strategy. Thus far, the data has led them to tentatively conclude

that subjects studying the elaborated version are more facile in solving problems that involve the manipulation of two or more variables.

As with the other techniques, verbal reports have some limitations. First, the amount of data that is produced using such techniques is considerable, therefore, reduction of the data is extremely time-consuming and tedious. This limitation results in either a) using probed recalls to focus on only particular aspects of the subjects' processing or b) limiting the number of subjects used in a study of this nature.

Second, verbal reports are subject to some of the same problems of other self-report data: Subjects may respond in a manner that the feel the researcher wishes to respond. In addition, subjects can discuss only that which is conscious on their part. Much of the processing that they engage in may be as hidden to the subject as it is to the researcher. This may lead subjects into making inferences about their own processing to complete incomplete recollections.

Third, and probably most significant, the procedures employed make more demands on the limited capacity of working memory than the learning task itself, leading researchers to question the validity of both the processing information and the task performance data. This is especially a limitation with concurrent verbal reports. The subjects' attempts to report their own processing may subvert their performances on the learning task which may in turn invalidate their processing techniques. Ericsson and Simon (1980) describe the limitations of verbal reports and the conditions under which such techniques are most valid. Some of their suggestions are that a) in concurrent reports, subjects should be asked **what** they are doing rather than **how** or **why** they are doing something, b) that retrospective reports follow immediately after the task and are cued by evidences of the subjects actions (such as video tapes of the subject completing the learning task), if possible, and c) that probing questions are very specific "Did you break the task into subgoals? Which subgoals did you break the task into" rather than general "Did you use a problem-solving technique?"

Representations of Cognitive Structure

The previous three techniques are used to make inferences about the cognitive processes that subjects engage in as they complete a particular learning task. The final category of techniques attempt to acquire a physical representation of the cognitive structures of subjects. Originally, these techniques were developed in order to compare the cognitive structures of learners with the content structure of material to which they have been exposed (Preece, 1976; Shavelson, 1972). These techniques may be used, however, to compare the mental representations of content that are developed as a result of studying two or more versions of instruction. In other words, they may be used to examine the effects of instructional variables on cognitive structure.

The data that is obtained from these techniques are indices of the semantic proximity or semantic distance between pairs of words. Several procedures that are used to gather this information are

- word association tests
- construction of linear graphs (trees)
- similarity ratings
- free recall (with an examination of extent to which particular words are clustered)
- sorting tasks (Preece, 1976)

The first three techniques are the most commonly used and will described in the following paragraphs. The reader may wish to refer to Preece for descriptions of the latter two techniques.

In word association tests subjects are presented with a stimulus words and are asked to respond with the first word, or all the words that they can think of. Scores that are generally obtained are a) the total number of responses to a stimulus word, b) the average number of responses to the stimulus words, c) the number of responses of a particular kind, and d) the overlap of response lists for pairs of concepts (Shavelson, 1974). The data can be reduced into a matrix of similarity coefficients which may in turn be analyzed statistically with factor analysis, multidimensional scaling, or hierarchical cluster analysis.

When using the second technique, construction of linear graphs, the researcher asks the subjects to draw a physical representation of a set of concepts. In this technique subjects may be given very directive instruction or they may be taught a graphing technique and later asked to use it. An example of directive instructions might be

> Below is an alphabetical list of 10 terms. Read the list carefully several times. From the list of terms, pick the two terms which you think are "most similiar" to each other. Write the pair you have chosen in the middle of the page and connect them with a line. Label this line 1. Go carefully over the remaining terms in the list and pick the term which you think is most similar to to either of the two terms you have already selected. Label the connecting line 2 . . . (Shavelson, 1974).

Subjects may also be taught a graphing technique such as networking (Daneareau, Collins, McDonald, Holley, Garland, Diekhoff, & Evans, 1979) or making pattern notes (Buzan, 1974; Jonassen, 1983) prior to being exposed to the learning task. After experiencing the instructional treatments, the subjects can be asked to make a graph of the content using the newly learned procedure.

These graphs are converted to symmetric proximity matrices. Then such statistical techniques as cluster analysis and multidimensional scaling may be used to uncover the structure underlying the data. Jonassen reports using a the program ALSCAL (Young & Lewyckyj, 1979) the scale the data.

Jonassen (1983) describes comparing the representations that were obtained using pattern notes and word association techniques. He found that "the clusters produced by scaling the relatedness coefficients and the distances between concepts are very similar." (p. 14)

Reseasrchers using the third technique, similarity ratings, provide subjects with paired concepts and ask the subjects to rate the concepts as to their similarity. For example, the subjects might be asked to rate two concepts on a scale of one to ten with one being "closest" or "most similar." These ratings can be converted to proximity matrices and then subjected to factor analysis or multidimensional scaling techniques. Some individuals in our field may have recently participated in Jonassen's study which collected similarilty ratings of instructional technology and related terms.

Summary

Four techniques from cognitive psychology literature were described: a) secondary task techniques -- latency data, b) eye-movement records -- eye fixations, c) introspective/retrospective verbal reports -- categories of processing activities, and d) representations of cognitives structures -- indices of semantic proximity. The characteristics of each technique, its advantages and limitations, were discussed. An example from instructional research of each technique was presented. It was suggested that several techniques can used together to get a profile of learners' processing and resulting structures. In addition, researchers might consider using these techniques in conjunction with posttest or other outcome information in order to explain the results the are obtained.

Analysis of Current Practice

The second part of this paper reports on a review of recently reported research in our field to examine the degree to which the four techniques described earlier have been used in studies reported in AECT publications.

Data Source

Articles and papers published in Educational Communication and Technology Journal 1983-1987 and the Proceedings of Selected Research Paper Presentations at the (1983-1987) Annual Convention(s) of the Asssociation for Educational Communications and Technology were reviewed. Although a larger sample of articles might have given a more accurate profile of use of the cognitive psychology techniques, I considered this sample to be quite adequate for an initial examination of the literature. This sample comprised 17 issues and 78 articles of ECTJ and five issues and 208 articles of the RTD Proceedings. A total of 286 articles were examined. Of these, 3 papers were eliminated as duplicates, leaving a total of 283 papers for review.

Procedure and Results

Each paper was reviewed and categorized with a series of nested categories. First, it was determined whether the article was data-based. **One hundred seventy-four** of the articles were so categorized. Articles that did not fall in this category were conceptual and advice-to-practice in nature. These articles were eliminated from further analysis.

Second, the remaining articles were categorized as to whether they investigated the effects of an instructional variable or instructional variables on learning outcomes. **One hundred and seventeen** of the articles met this criterion. For the purposes of this study, articles that examined the effects of an instructional program, such as Logo, or an instructional medium, such as media comparison studies, were eliminated from this category. Studies that did not fall into the instructional variable effects category were eliminated from further analysis.

Next, the 117 articles were examined and categorized as to whether they explicitly espoused a cognitive psychology theoretical framework. To be so categorized the author(s) must have explicitly referenced cognitive processes or structures in substantiating predictions, in explaining treatments, or in discussing results. **Sixty-six** articles were included in this category. The articles not included in the category used other theoretical frameworks, such as social learning theory; used previous research as a framework; predicted or explained results in terms of intuition or pragmatic conclusions, or did not include a framework. Articles not included in this category were not analyzed further.

Finally, the 66 articles were analyzed as to data-gathering techniques and dependent measures to ascertain which used the four techniques described above. Of the 66 articles, only **six** were so categorized: one used response latency data, three used eye movement data, three used verbal reports, and none used mental representations. One study used two of the above techniques, so was tallied twice. It should be noted that several of the articles that did not reach this level of categorization included these techniques, (e.g., Jonassen's article comparing the mental representations achieved through word association and pattern notes techniques). An examination of the articles did not reveal any similar techniques not included in the previous discussion but appropriate techniques for examining cognitive processing or structures. The vast majority of studies classified in this final category collected only posttest data.

Discussion and Conclusion

An examination of 283 articles published in the field of instructional technology revealed that only six of the articles that examined the effects of instructional variables on learning outcomes and claimed a cognitive psychology framework used the techniques described in this paper. While there may be some error in categorizations, this finding represents a fairly accurate analysis of the current use of the techniques that have been suggested in cognitive psychology literature as indications of cognitive processing and cognitive structures. One might conjecture as to why this is the case. Researchers in the field may

- be most concerned with the ultimate question -- which instructional variables have the greatest effect on performance?
- not have resources and training to employ the these techniques,
- not consider the information that these data provide of value, or
- be unaware of these techniques and their potential.

If this latter conjecture has any validity (and it may as information describing these techniques is not synthesized in any source that I located, with the exception of a brief review of the first three techniques by E. Gagne, 1985) then perhaps this paper may provide a beginning point for researchers to examine the techniques' potential.

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